# Thermal dielectron measurements in Au+Au collisions at BES-II energies with the STAR experiment

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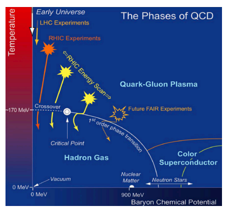
## Abstract

Dielectrons, emitted during the evolution of the hot and dense QCD medium created in relativistic heavy-ion collisions, offer an effective probe of the hot medium, as they are not coupled to strong interaction. The dielectron emission rate is proportional to the medium's electromagnetic spectral function. In the dielectron mass region $M_{ee} < 1$ GeV/c$^2$, the spectral function probes the in-medium ρ meson propagator which is sensitive to the medium's properties including the total baryon density and the temperature. Measuring thermal dielectron production allows us to investigate the microscopic interaction mechanism between the electromagnetic current and the medium, along with exploring various medium properties.

In this poster, we will report STAR measurements of thermal dielectrons produced in Au+Au collisions at $\sqrt{s_{NN}}$ = 7.7, 9.2, 11.5, 14.6, and 19.6 GeV. The results will include thermal dielectron invariant mass spectra, excess yields and temperature measurements. In addition, these preliminary results will be compared to the results from STAR BES-I and theoretical model calculations for the discussions of the physics implications.


## Dileptons as Probe

- RHIC BES program explores the phases of QCD by colliding Au+Au at different center-of-mass energy.

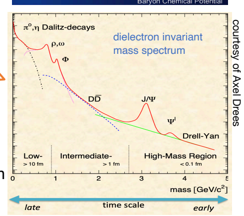



**✦ Why Dileptons?**

- No coupling to strongly interacting matter.
- Mean free path length ≫ size of the fireball.
- No blue-shift effect.
  - Encode important information: invariant mass.

**✦ Dielectron in thermal equilibrium medium:**

- Interested signals: QGP radiation & In-medium vector mesons.



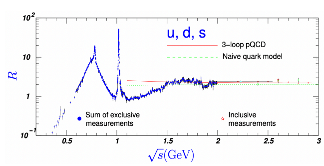

Production Rate $R_{ee} \propto \mathrm{Im}\,\Pi_{EM}$ EM spectral function

## EM Spectral Function & Vector Meson Dominance

**✦ EM spectral function [1]:**

- $M_{ee} > 1.5$ GeV/c$^2$: Partonic dominance.
- $M_{ee} < 1.1$ GeV/c$^2$: Vector Meson dominance (VDM).

$$\mathrm{Im}\Pi_{EM} \sim [\mathrm{Im}D_\rho + \frac{1}{9}\mathrm{Im}D_\omega + \frac{2}{9}\mathrm{Im}D_\phi]$$



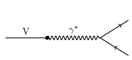

**✦ Hadronic many-body approach:**

- ρ meson propagator in the hot and dense hadronic matter [2]:

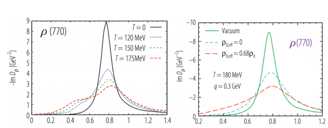
$$D_\rho = \frac{1}{M^2 - (m_\rho^0)^2 - \Sigma_{\rho\pi\pi} - \Sigma_{\rho M} - \Sigma_{\rho B}}$$

$\Sigma_{\rho\pi\pi}$ Pion cloud

$\Sigma_{\rho B,M}$ Scattering with baryon & meson

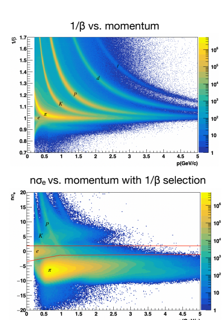


$$R = \frac{\sigma(e^-e^+ \rightarrow \mathrm{hadron})}{\sigma(e^-e^+ \rightarrow \mu^-\mu^+)}$$

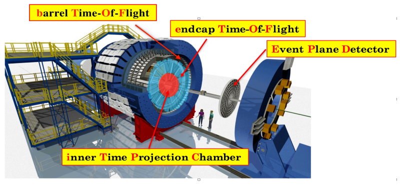



Broadening of ρ meson width depends on Temperature and Total Baryon Density

## STAR experiment

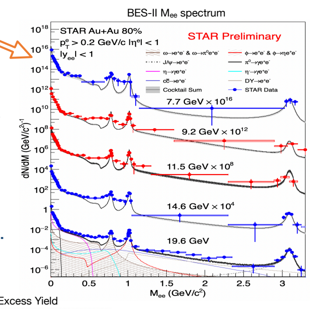


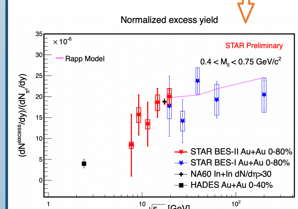

- STAR experiment PID system [3]: Time Projection Chamber + Time of Flight detectors.
  - Momentum measurement.
  - dE/dx ($n\sigma_e$) and velocity($1/\beta$).

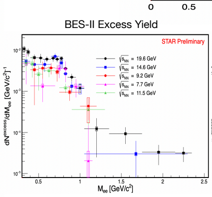


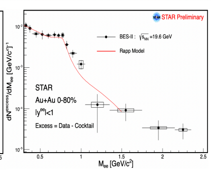

## Dielectrons as Spectrometer

- BES-II dielectron invariant mass spectrum and excess yield (ρ + QGP).
  - Comparison of excess yield spectra at 19.6 GeV shows the effectiveness of Rapp's model at high $\mu_B$.
- Integral of normalized excess yield [4] at BES-II and HADES [6] hints a decreasing trend from high to low $\sqrt{s_{NN}}$.

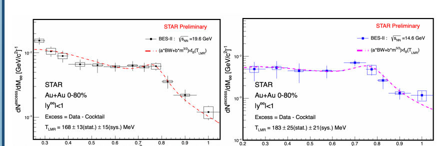



## Dielectrons as Thermometer

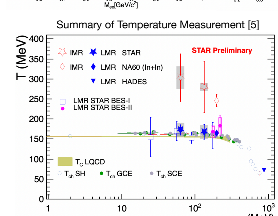



Low Mass Range (LMR) fitting function:

$$(a * BW + b * M_{ee}^{3/2}) * e^{-M_{ee}/T}$$

Breit-Wigner (BW) function:

$$\frac{M_{ee}\, M_0\, \Gamma}{(M_0^2 - M_{ee}^2)^2 + M_0^2\,\Gamma^2}$$




- First temperature measurement in STAR BES-II energies.
- $T_{LMR} \sim T_{pc}$ (pseudo critical temperature).
- Radiation from hadronic gas: mainly produced around the phase transition.

## Summary and Outlook

- Dileptons can provide access to various physics observables: vector meson spectral function, medium temperature.
- ▸ ML methods to reduce photonic conversion background.
- ▸ Comparisons with theory calculations to constrain models and further physics interpretations especially on the decreasing trend.
- ▸ Opportunities for other topics with electromagnetic probes: conductivity, dielectron angular distributions.


## Reference

[1] **R.L. Workman et al. (Particle Data Group),** Prog. Theor. Exp. Phys. 2022, 083C01 (2022).
[2] **M. Urban, M. Buballa, R. Rapp, and J. Wambach,** Nucl. Phys. A 673, 357 (2000).
[3] **STAR Beam Use Request** 2019/2020 (SN696)
[4] **STAR Collaboration,** Phys. Rev. C 107, L061901 (2023).
[5] **STAR Collaboration,** arXiv: 2402.01998.
[6] **HADES Collaboration,** Nature Physics 15 (2019) 1040.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